清華大學
Tsinghua University

XENON

The XENON Dark Matter Search Experiment

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On behalf of the XENON Collaboration

TeVPA 2021, Chengdu
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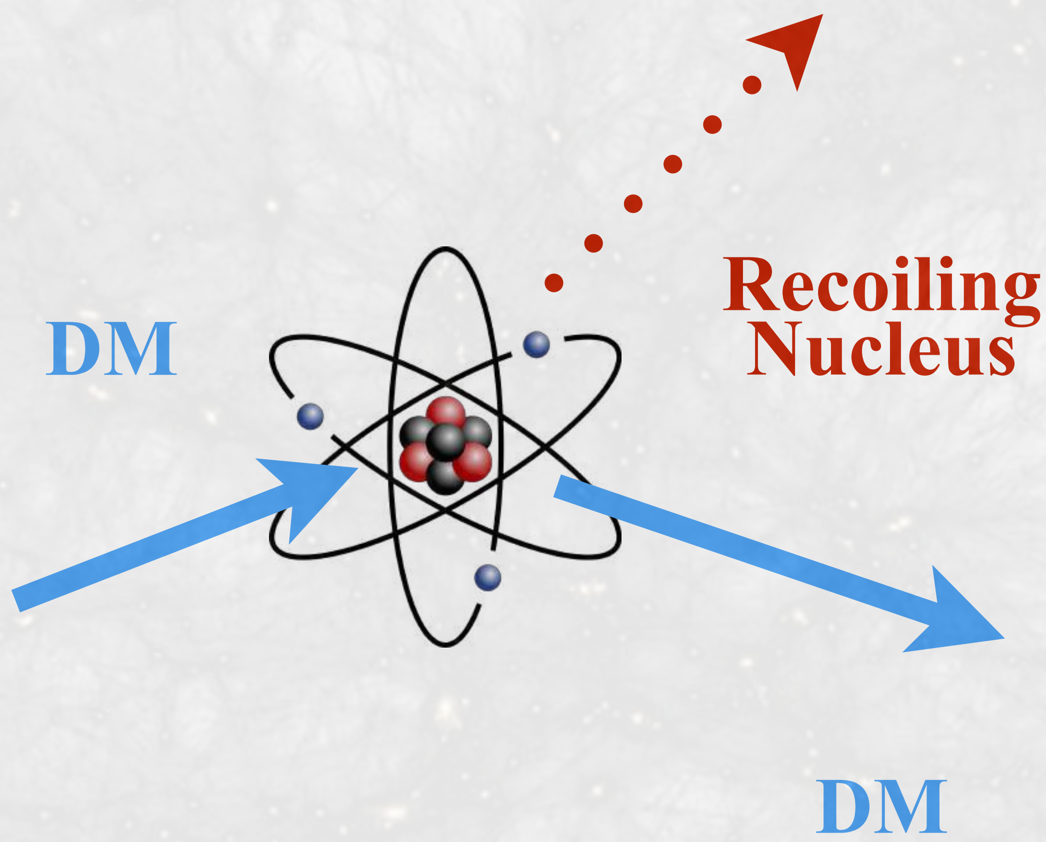
Direct Detection of Dark Matter

PHYSICAL REVIEW D VOLUME 31, NUMBER 12 15 JUNE 1985

Detectability of certain dark-matter candidates

Mark W. Goodman and Edward Witten
Joseph Henry Laboratories, Princeton University, Princeton, New Jersey 08544
(Received 7 January 1985)

We consider the possibility that the neutral-current neutrino detector recently proposed by Drukier and Stodolsky could be used to detect some possible candidates for the dark matter in galactic halos. This may be feasible if the galactic halos are made of particles with coherent weak interactions and masses $1-10^6$ GeV; particles with spin-dependent interactions of typical weak strength and masses $1-10^2$ GeV; or strongly interacting particles of masses $1-10^{13}$ GeV.



$$\frac{dR}{dE_{nr}} \propto N \, \frac{\rho_\chi}{2 m_\chi m_r^2} \, \sigma_N \, \left| F^2(E_{nr}) \right| \int_{v_{\min}}^{v_{esc}} \frac{f(v)}{v} \, d^3v$$

- N: number of targets
- ρ_χ: DM density
- m_χ: DM mass
- σ_N: interaction cross section
- $\left| F^2(E_{nr}) \right|$: nuclear effects
- $\int_{v_{\min}}^{v_{esc}} \frac{f(v)}{v} d^3v$: WIMP velocity distribution

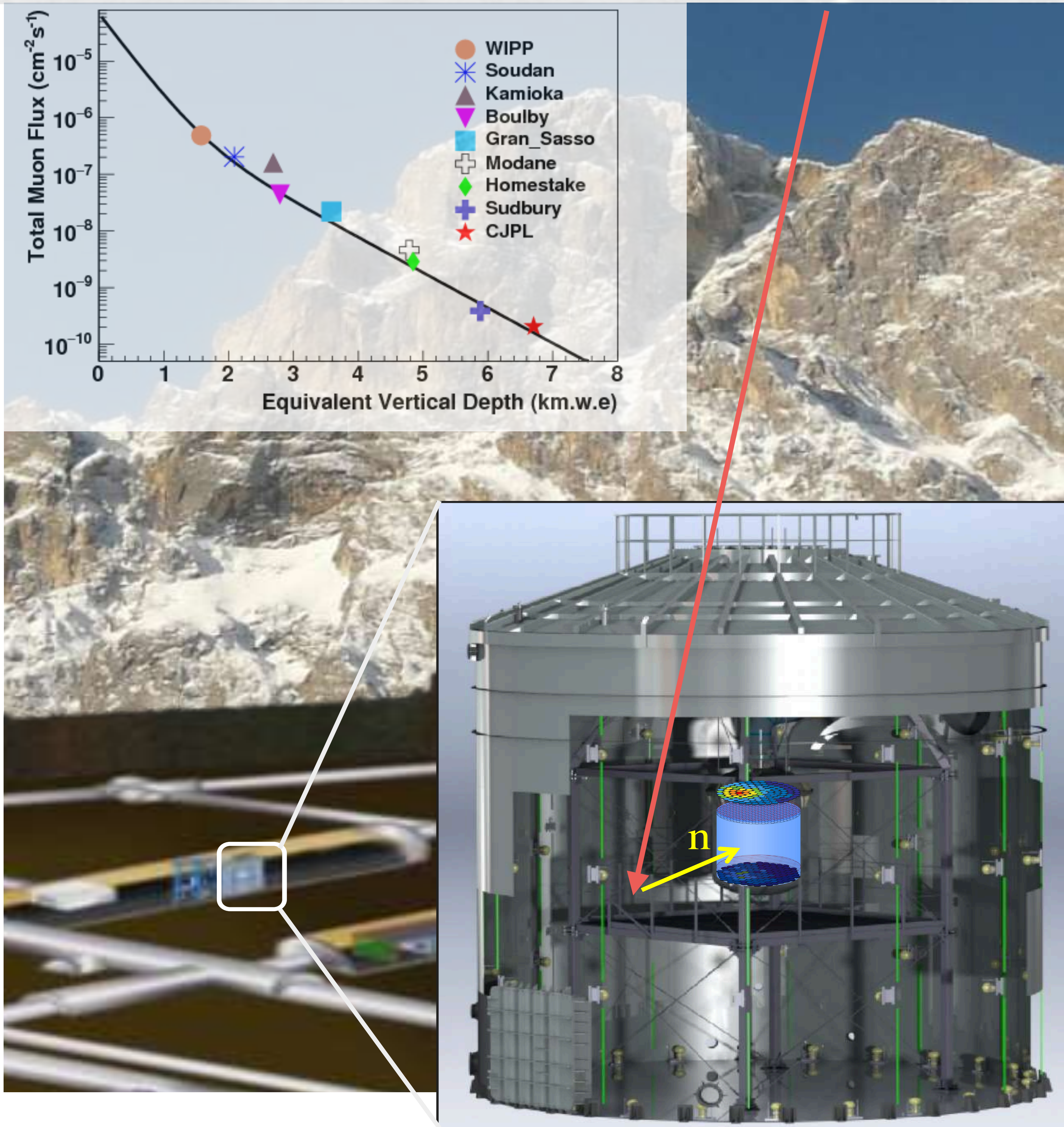
The XENON Collaboration

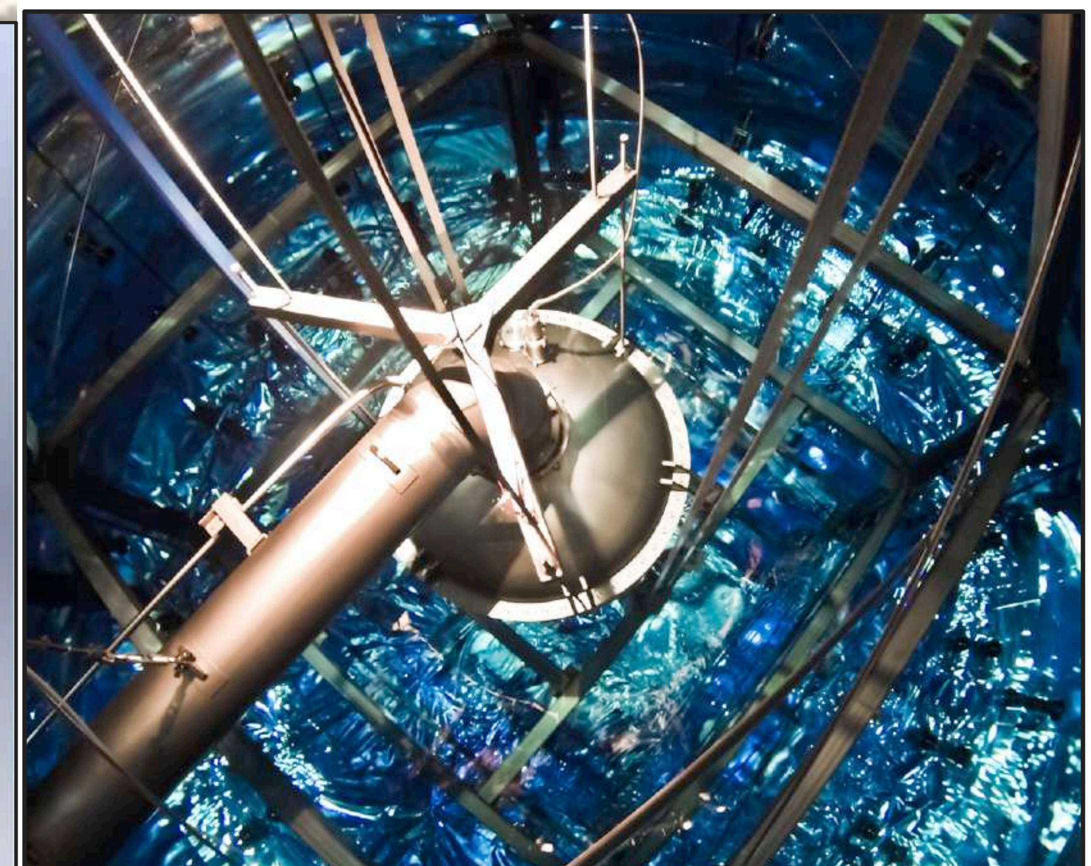
Development of XENON Program




XENON10	XENON100	XENON1T	XENONnT
2005-2007	2008-2016	2012-2018	2019-202x
25 kg - 15cm drift	161 kg - 30 cm drift	3.2 ton - 1 m drift	8.6 ton - 1.5 m drift
$\sim 10^{-43}$ cm^2	$\sim 10^{-45}$ cm^2	$\sim 10^{-47}$ cm^2	$\sim 10^{-48}$ cm^2

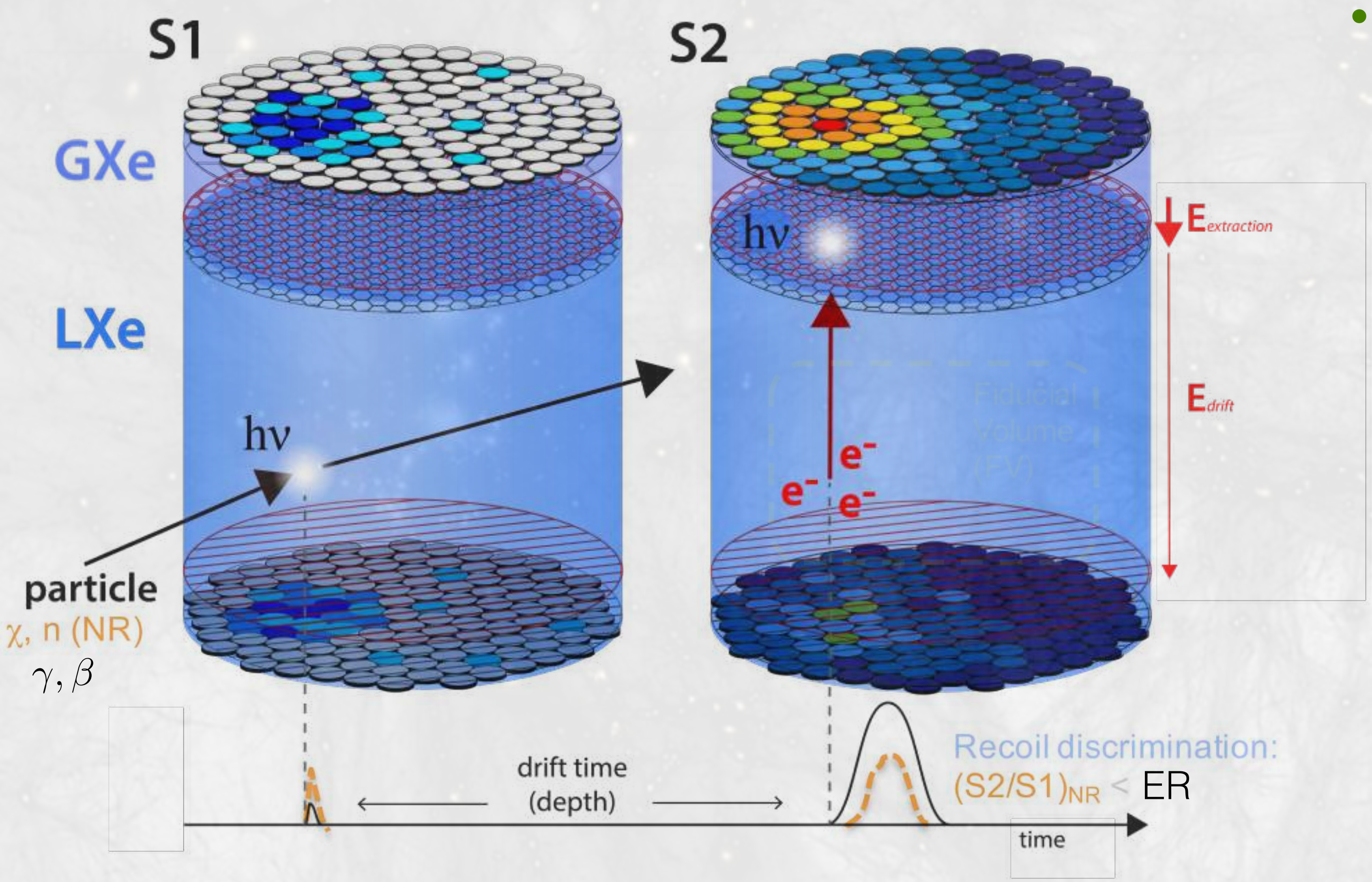
Gran Sasso: The XENON Shield



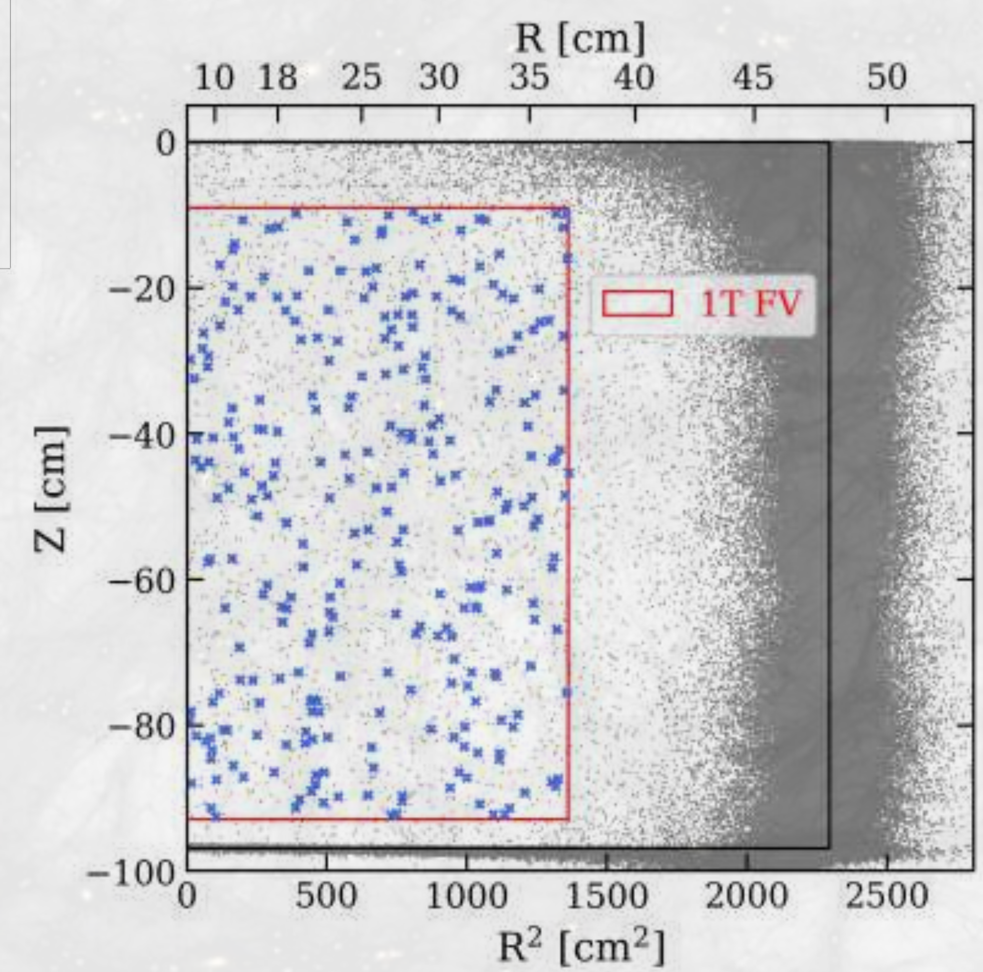


Two-phase Xe Time Projection Chamber

- **Scintillation light - S1**
- **Ionization electron -S2**



- two signals for each event:
  - 3D event imaging: x-y (S2) and z (drift time)
  - self-shielding, surface event rejection, single vs multiple scatter events



Two-phase Xe Time Projection Chamber

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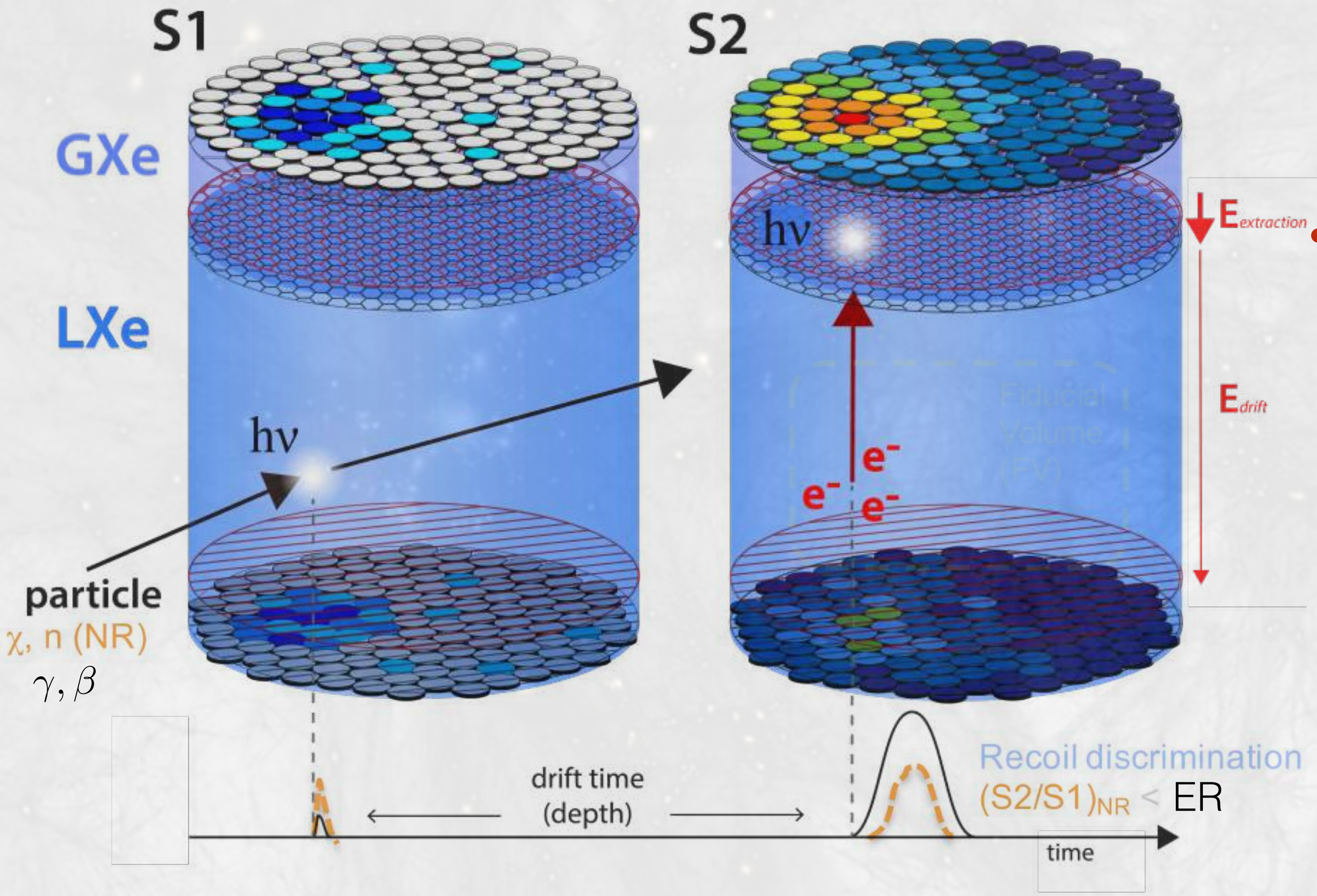
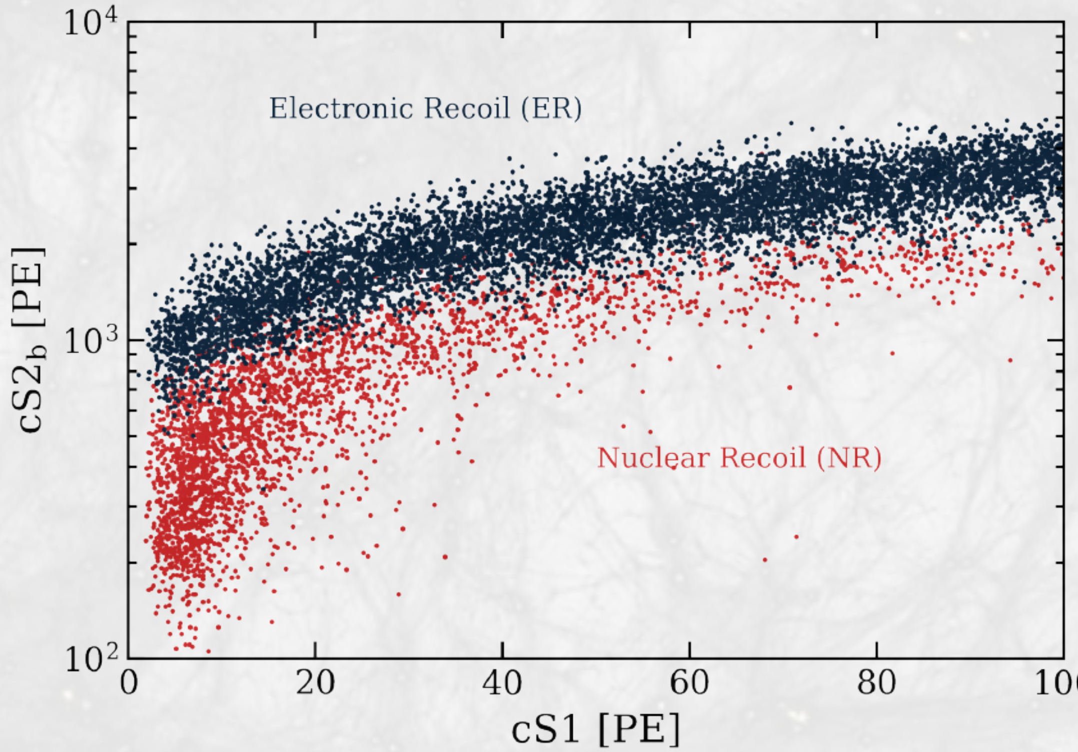
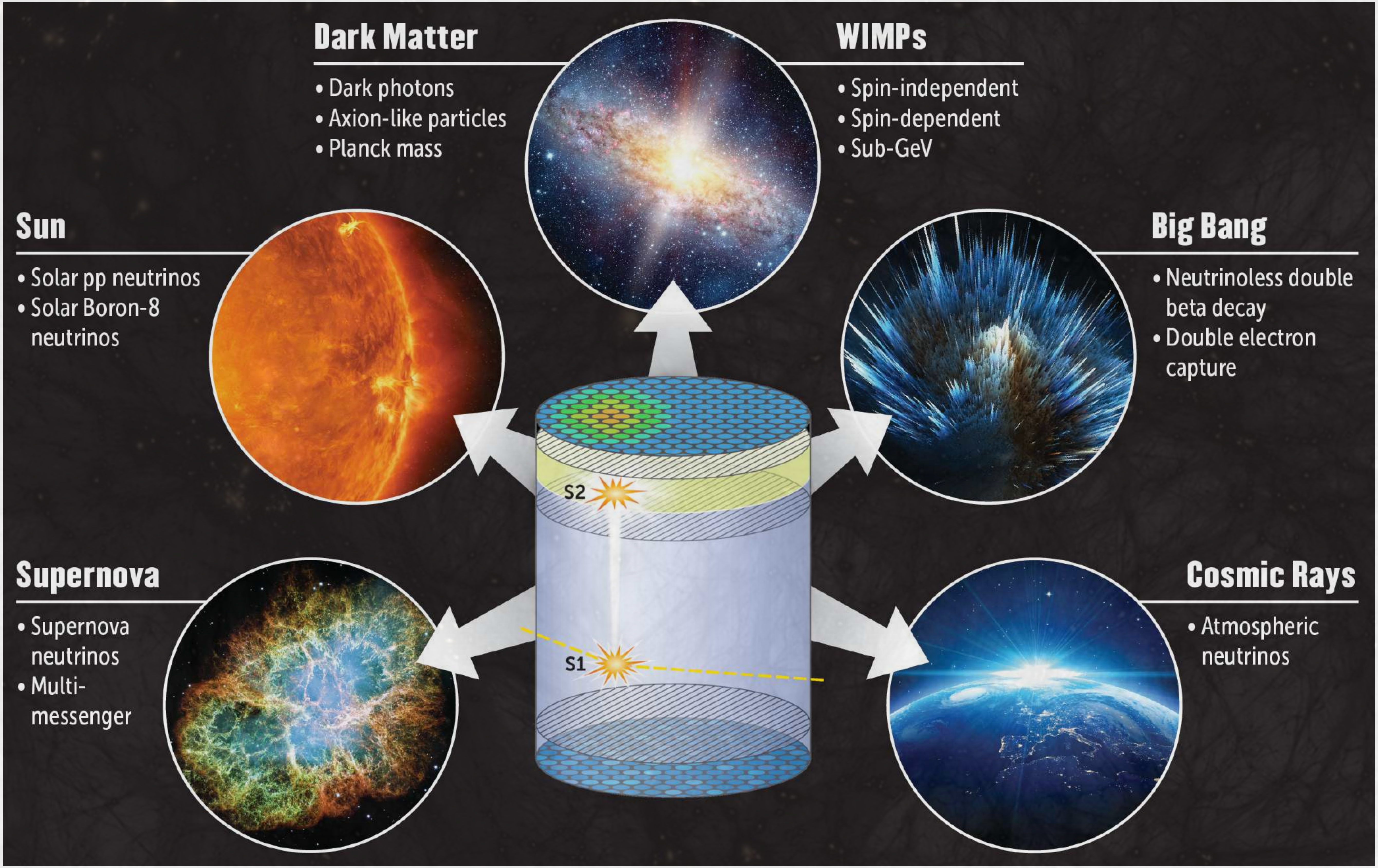


- two signals for each event:
  - 3D event imaging: x-y (S2) and z (drift time)
  - self-shielding, surface event rejection, single vs multiple scatter events
- Recoil type discrimination from ratio of charge (S2) to light (S1)



What do We Search in XENON

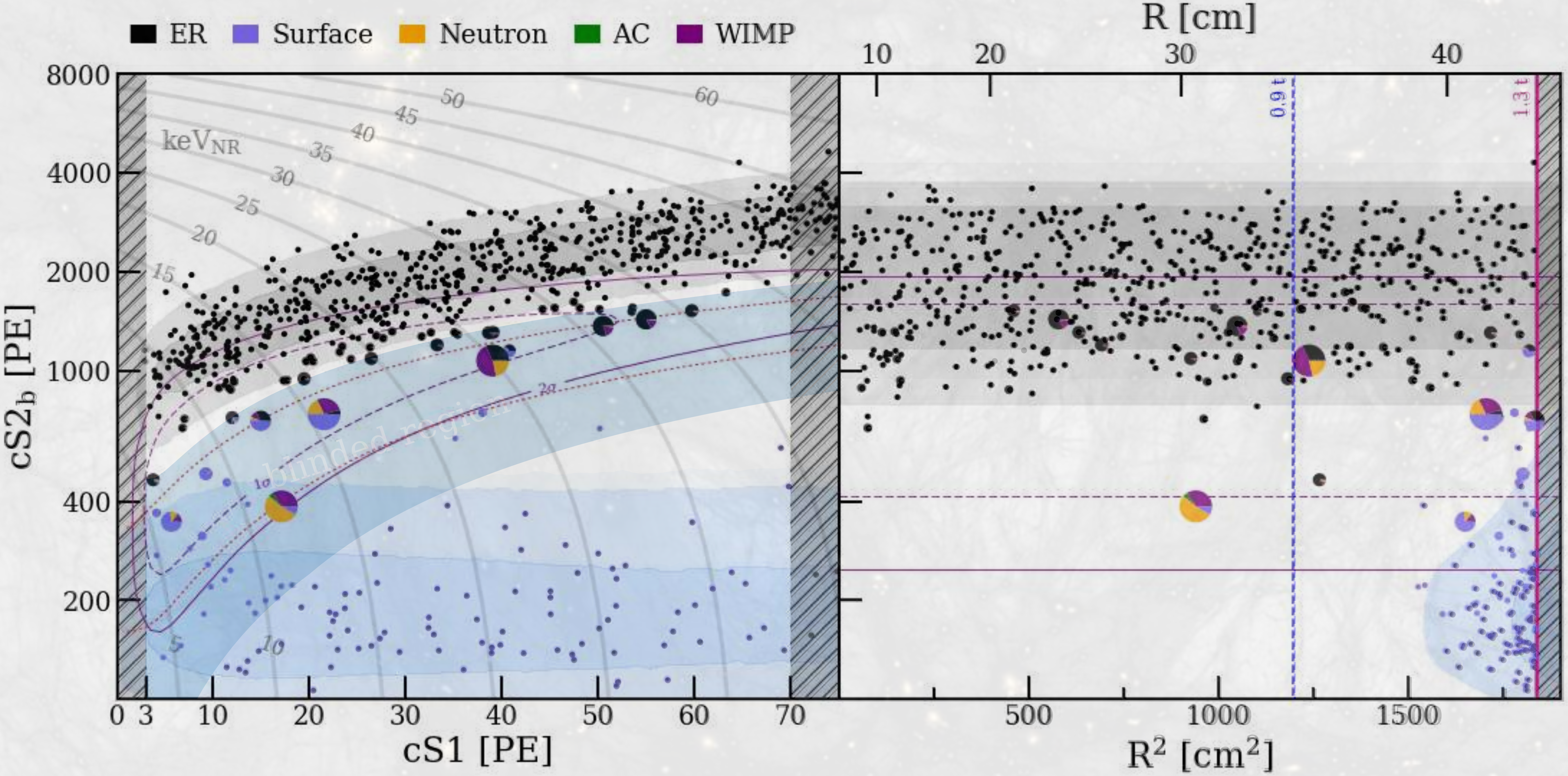


Dark Matter Search Results

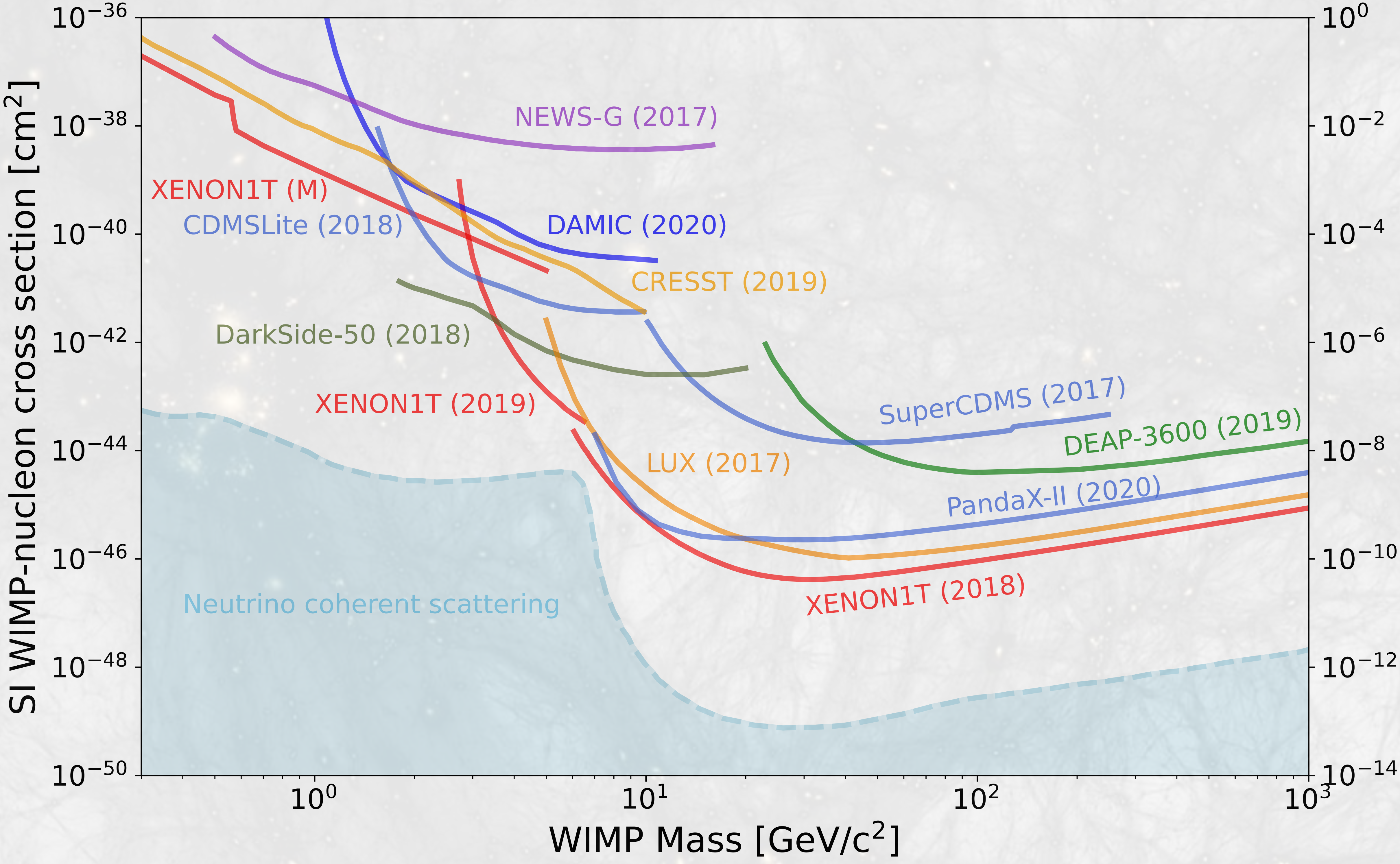
No significant Excess!

PRL 121, 111302 (2018)

Source	1.3 t	1.3 t, NR Ref.	0.9 t, NR Ref.
ER	627 ± 18	1.6 ± 0.3	1.1 ± 0.2
Radiogenic	1.4 ± 0.7	0.8 ± 0.4	0.4 ± 0.2
CEνNS	0.05 ± 0.01	0.03 ± 0.01	0.02
Accidental	$0.5^{+0.3}_{-0.0}$	$0.10^{+0.06}_{-0.00}$	$0.06^{+0.03}_{-0.00}$
Surface	106 ± 8	4.8 ± 0.4	0.02
Total	735 ± 20	7.4 ± 0.6	1.6 ± 0.3
200 GeV WIMP	3.6	1.7	1.2
Data	**739**	**14**	**2**



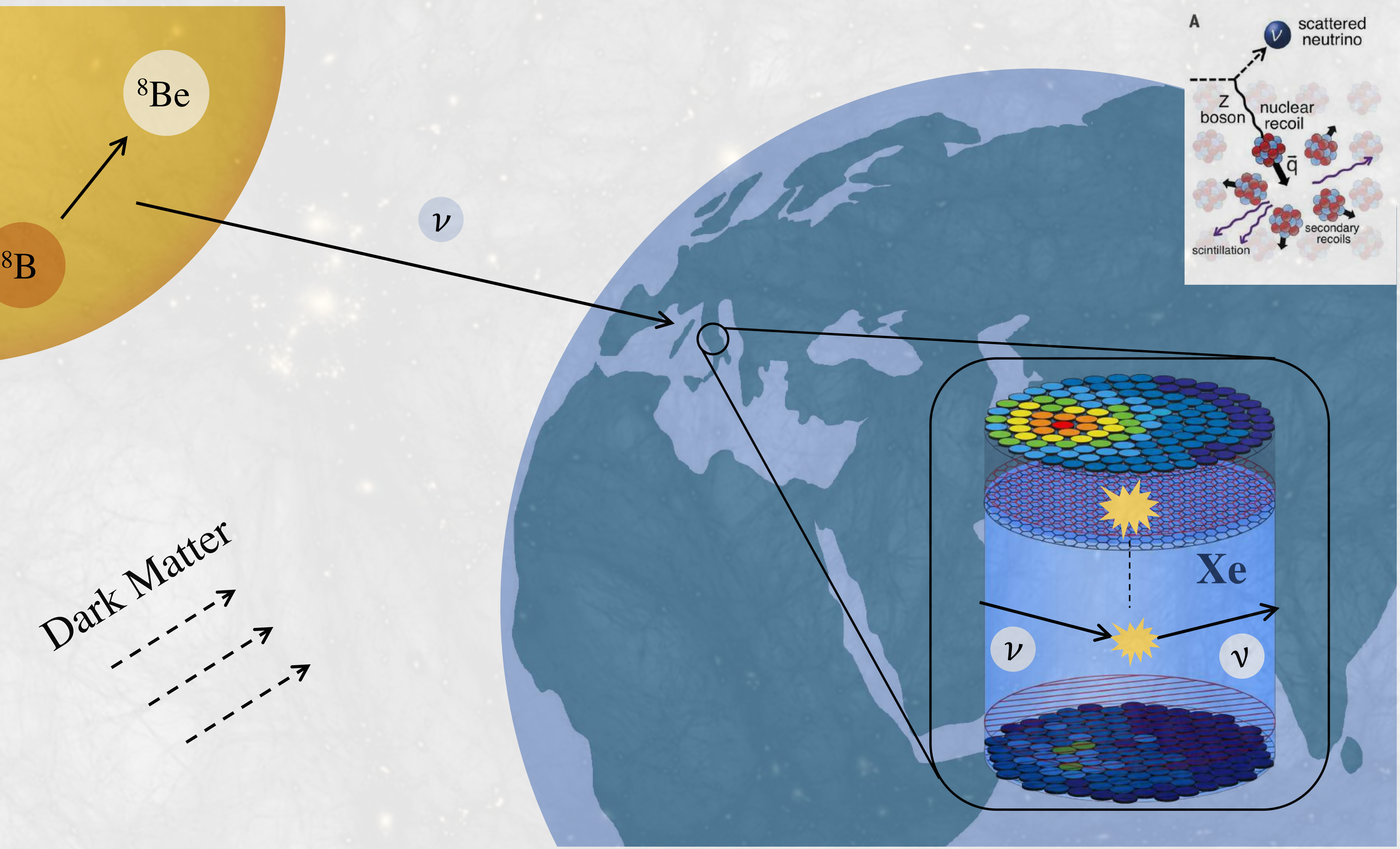
Constraints on Dark Matter Interactions



Solar B8 “Neutrino Fog”

$$R = \phi(\nu) \times \sigma_\nu \times N_{Xe} \times \text{exposure}$$
$$\simeq 600\,\text{events}/(\text{tonne} \times \text{year})$$

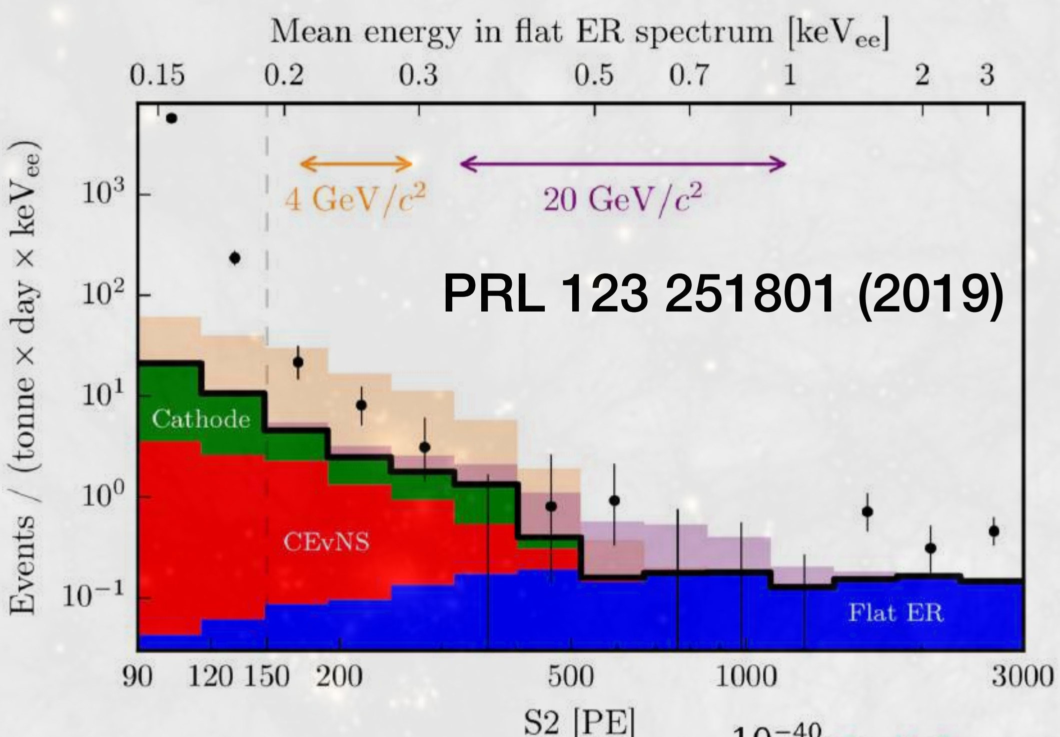
PRL 126, 091301 (2021)



Analysis towards the B8 "Neutrino Fog"

#1: "S2-only" approach

A limit setting analysis (expect 2.0±0.3 CEvNS)

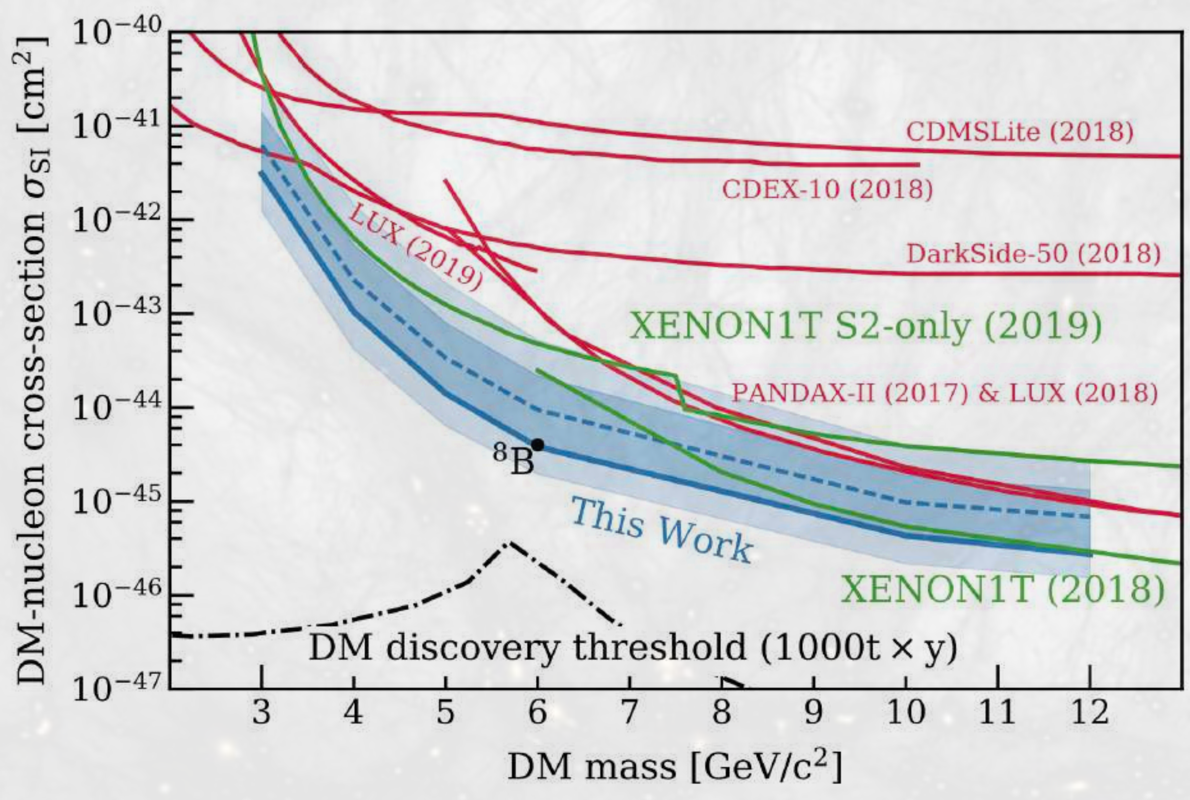


#2: lowering S1 & S2 together

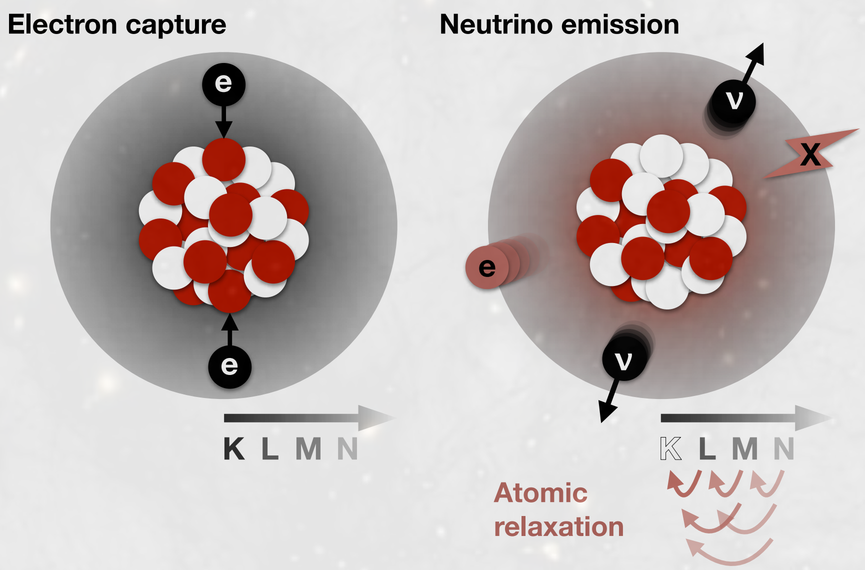
- S1: 2 or 3 photons
- S2: ~4 - 18 electrons

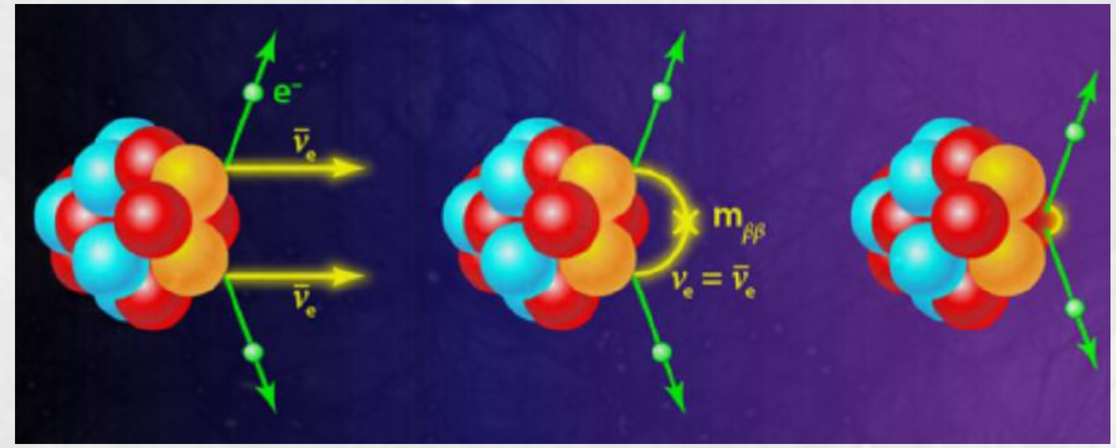
PRL 126, 091301 (2021)

Source	Expectation
CEvNS	**2.25**
Accidental	5.14
ER	0.21
Radiogenic	0.03
Total	7.65



Search for Double Beta Decays



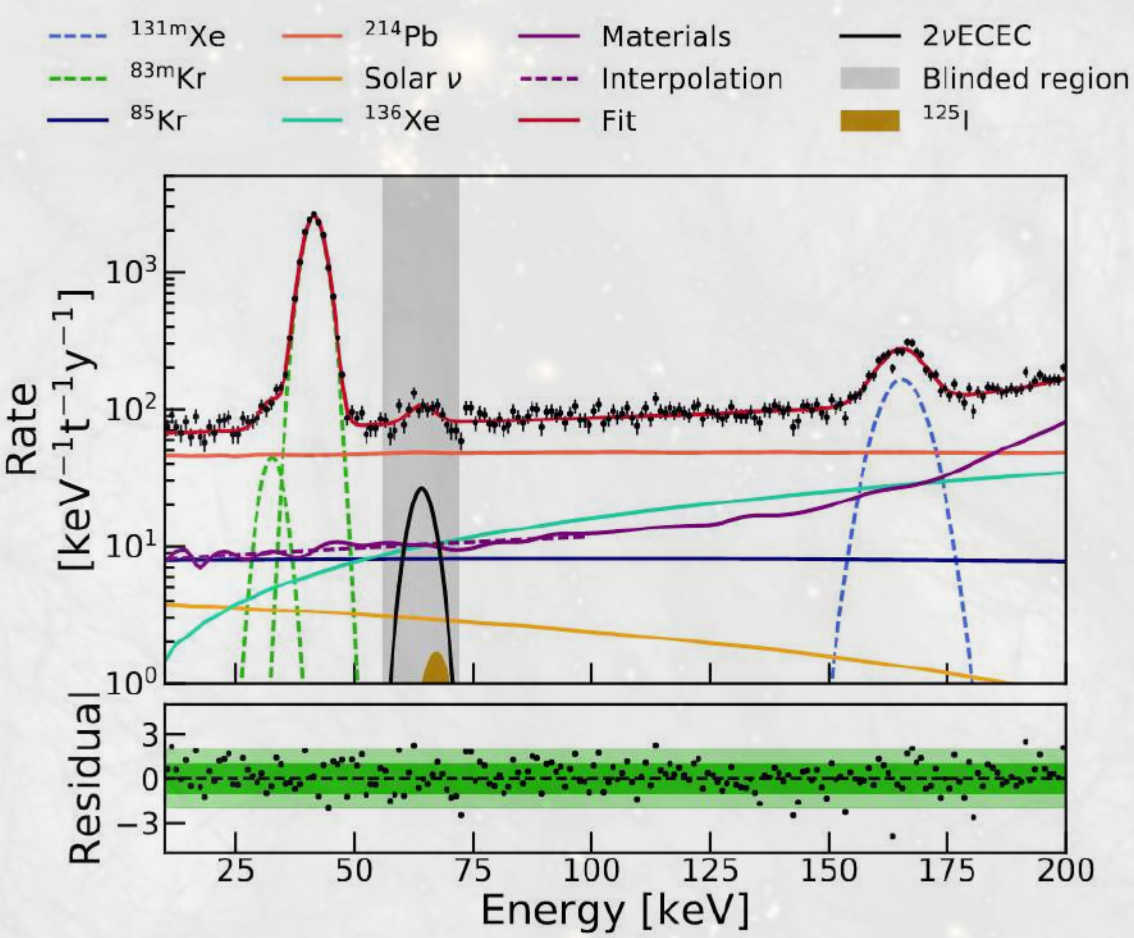


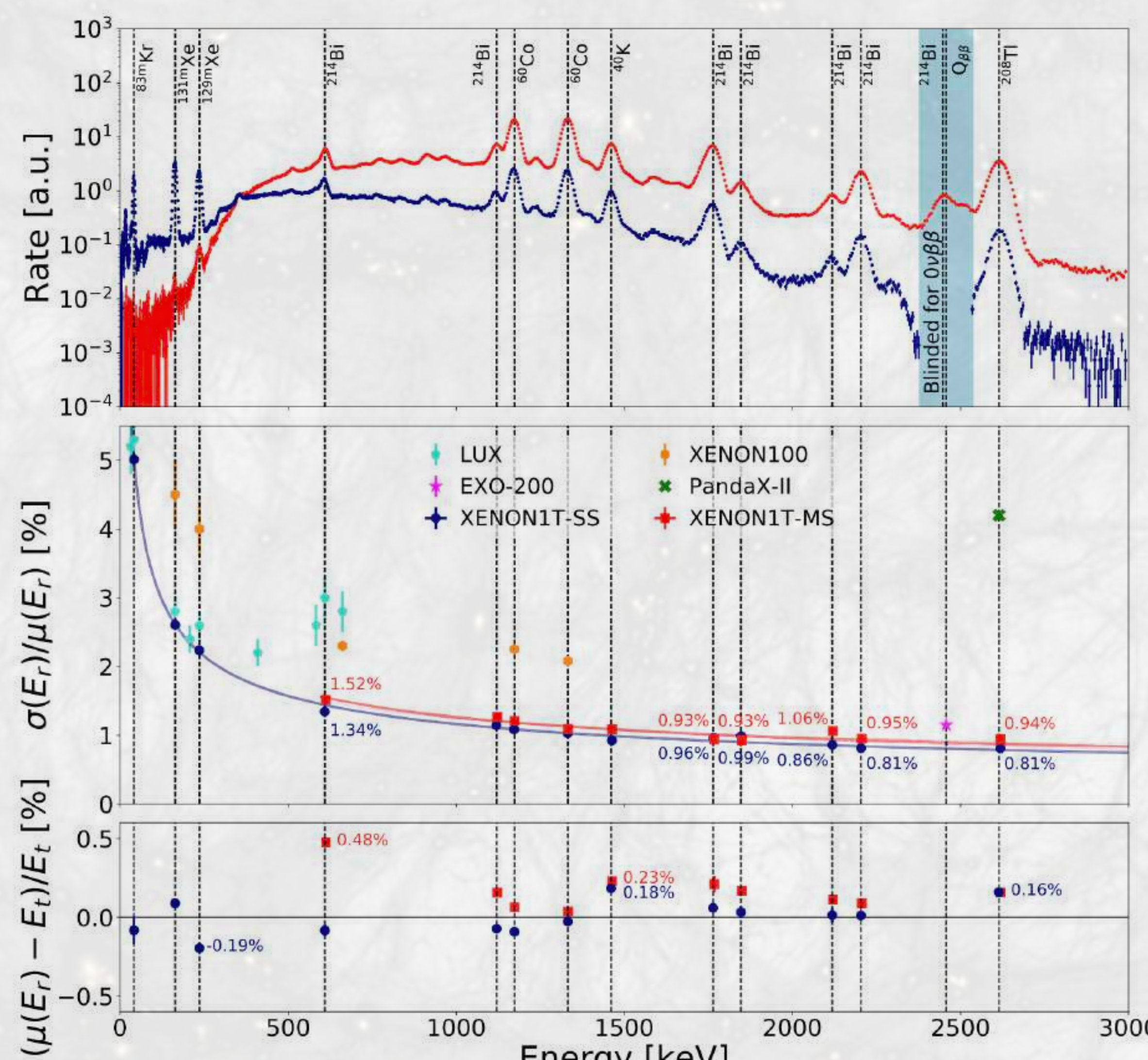
$^{124}Xe + 2e^- \rightarrow {}^{124}Te + 2\nu_e$

EPJ-C (2020), 80: 785

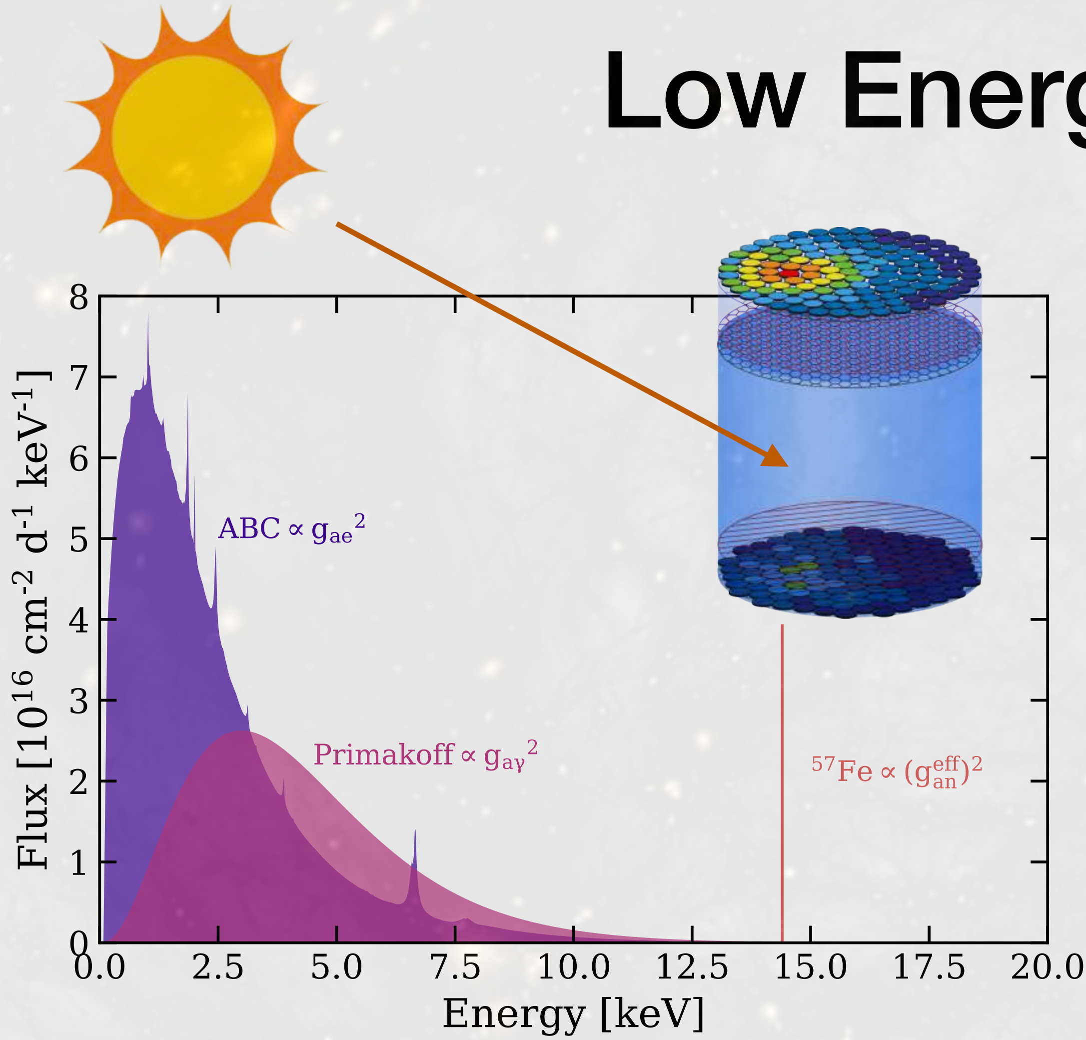
resolution @ 2.5MeV: 0.8%

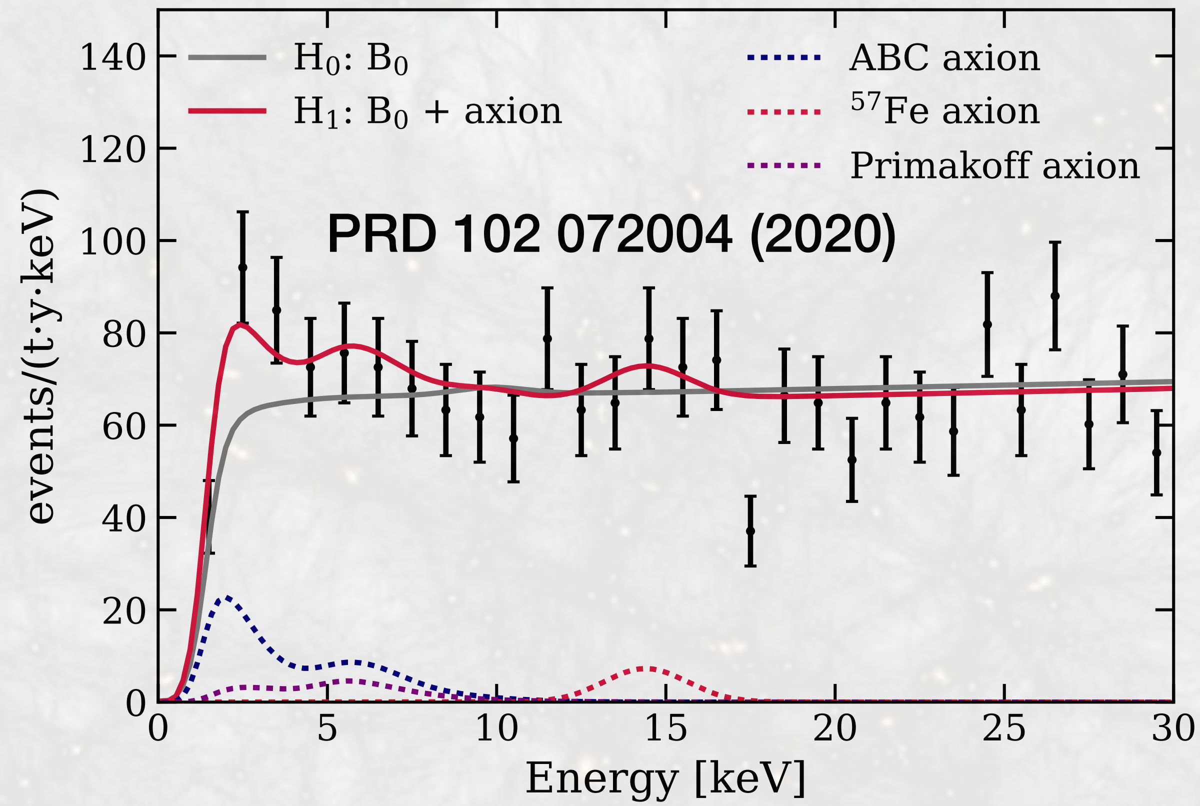
Nature 523,568 (2019)

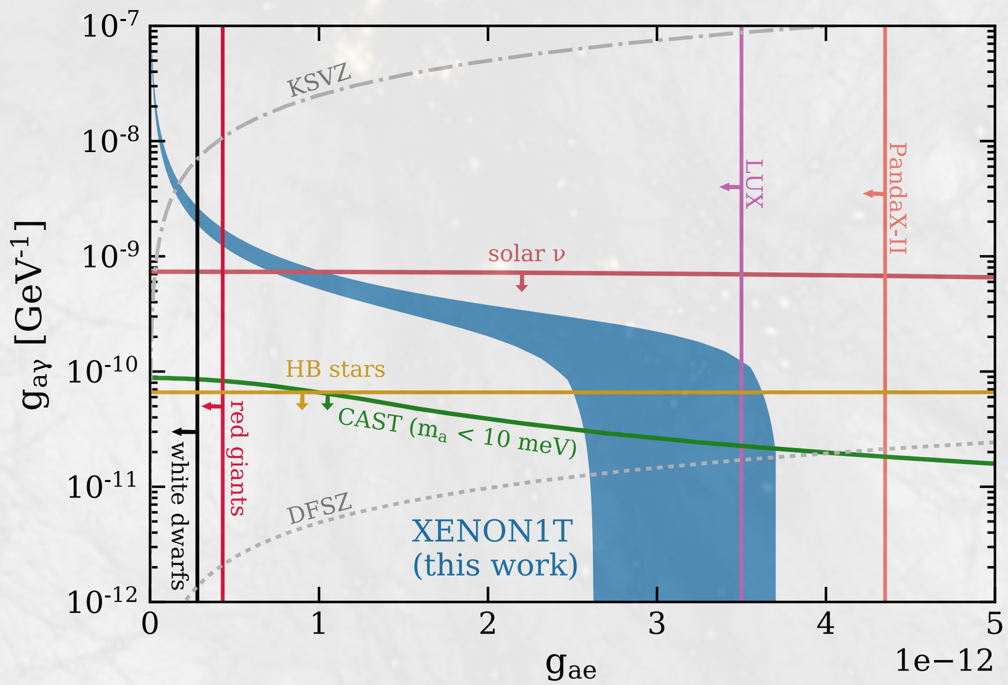




Low Energy ER Background

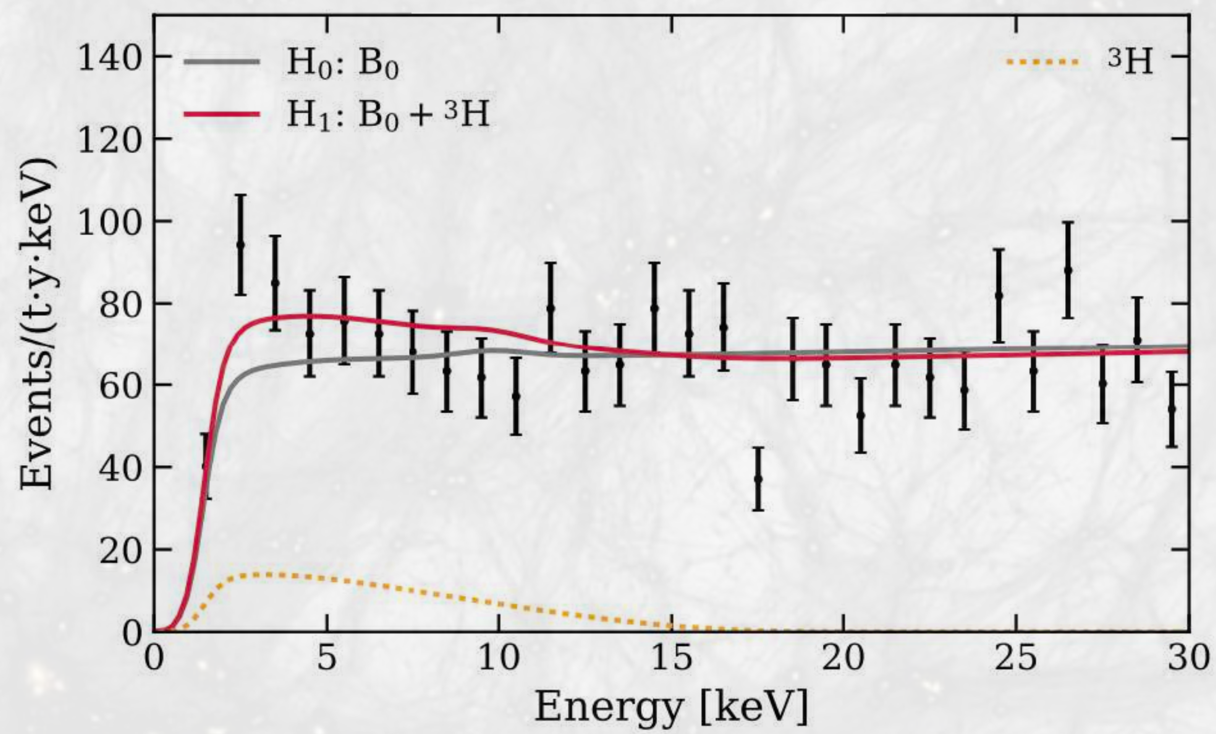






Axion explanation is in tension with stellar constraints

Tritium? Possible!



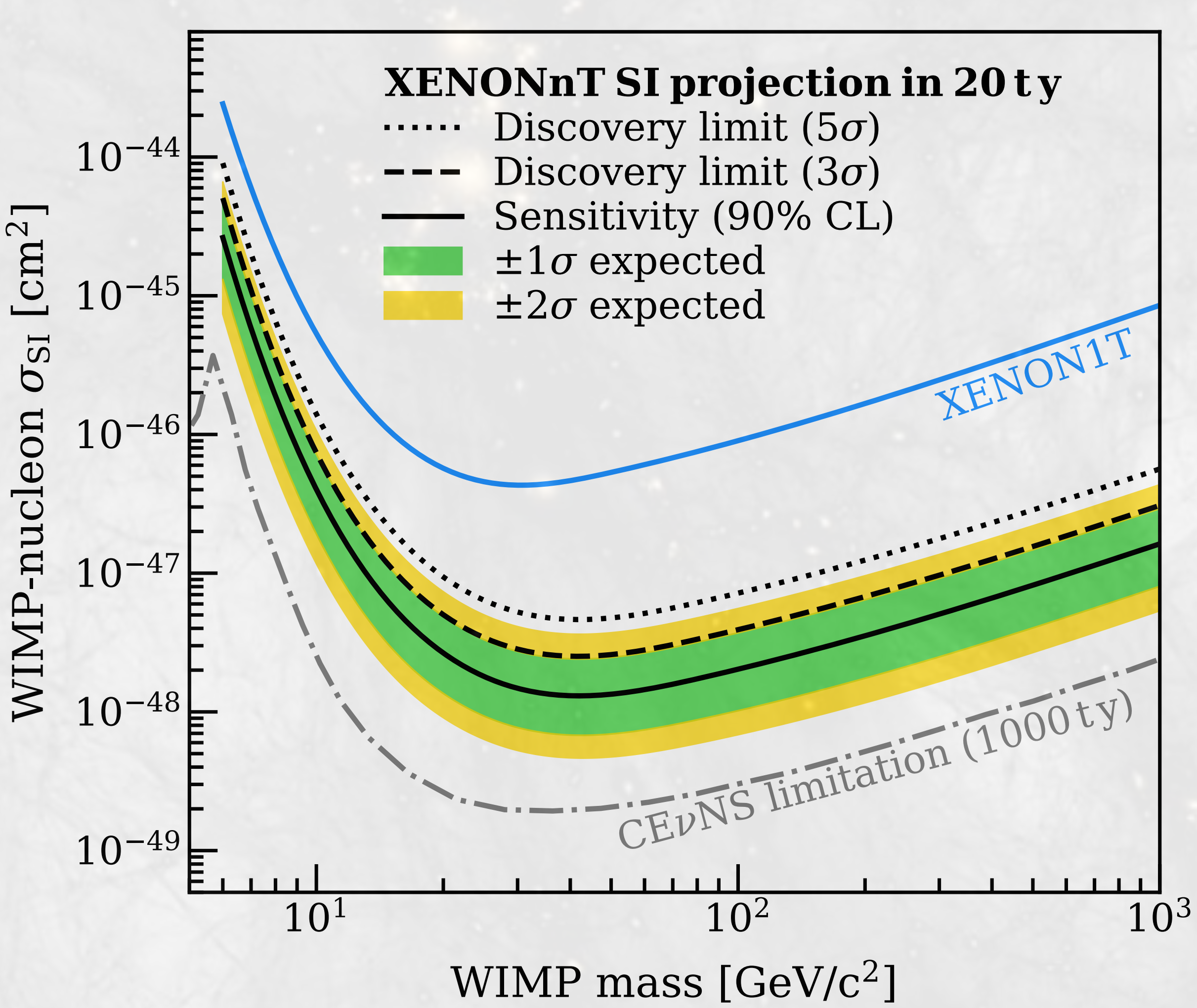
XENONnT: Currently running at Gran Sasso

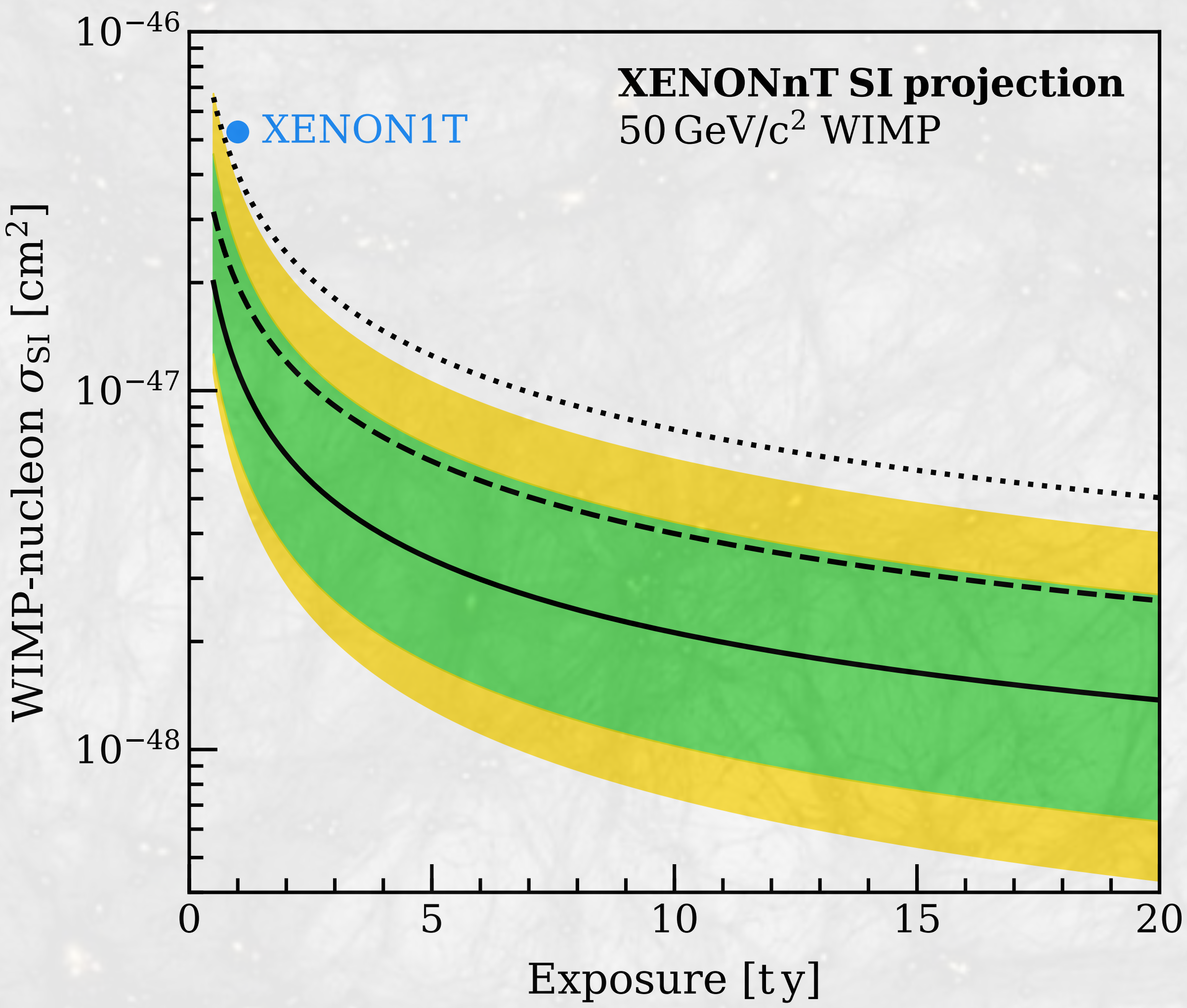
Goal: ~4.0 ton fiducial volume

~1/6 XENON1T ER background level

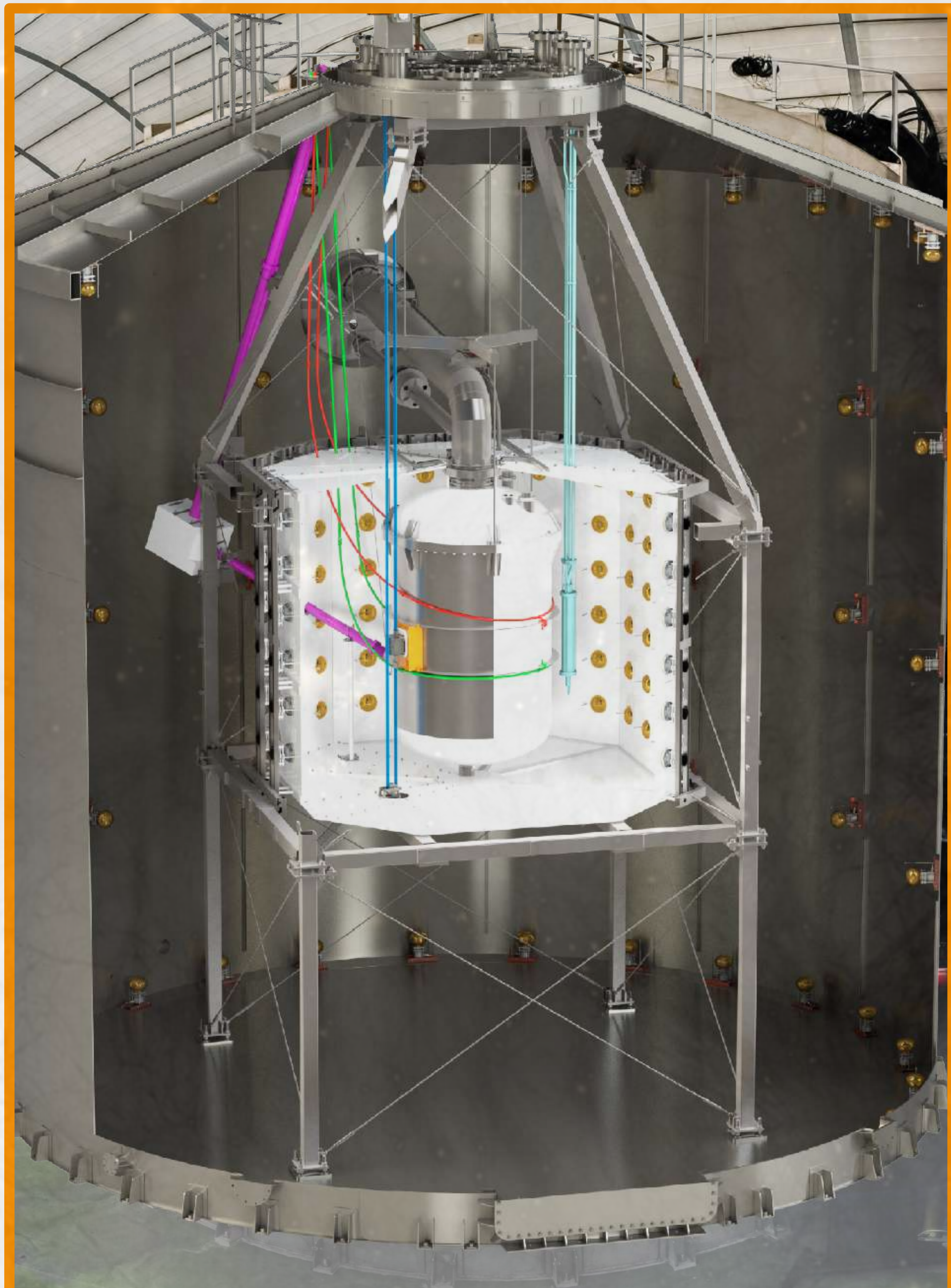
~1 neutron induced background in 20 ton-year exposure

JCAP 11 (2020) 031



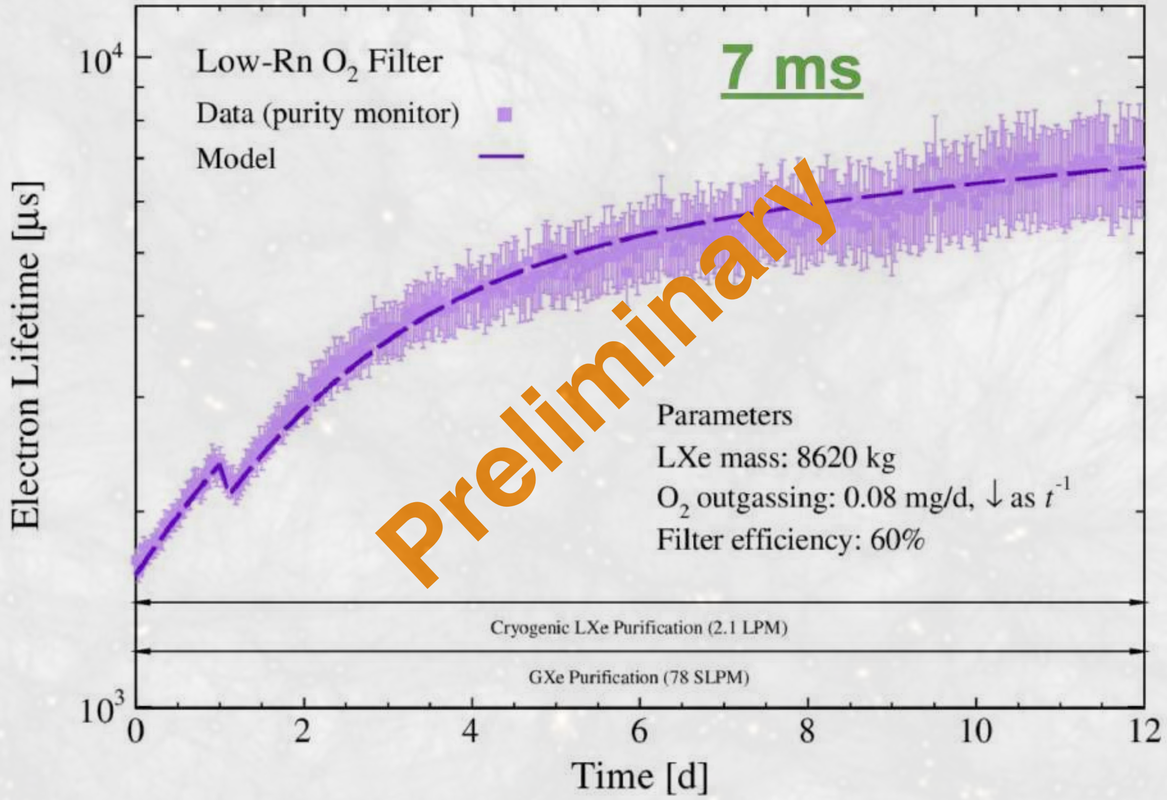


Upgrading to XENONnT

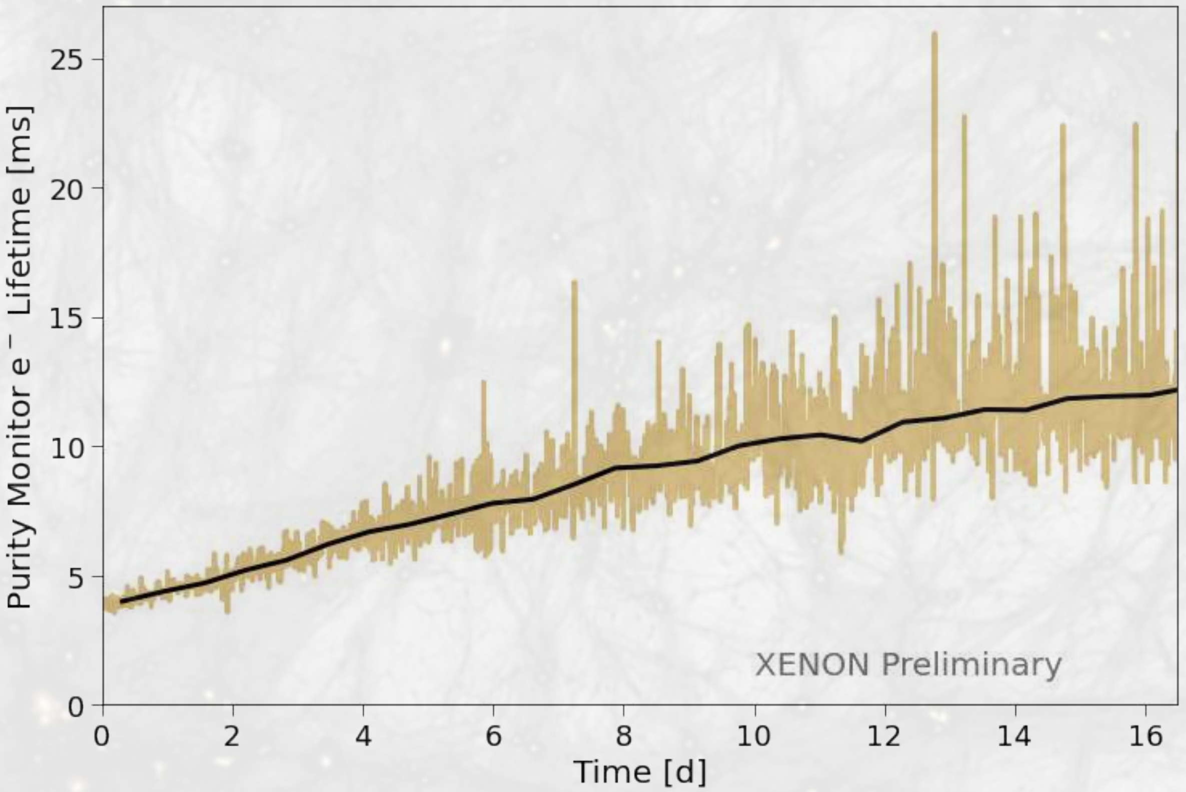


XENONnT Cryogenic Liquid Purification

Cryostat is filled with ~8.5t of LXe



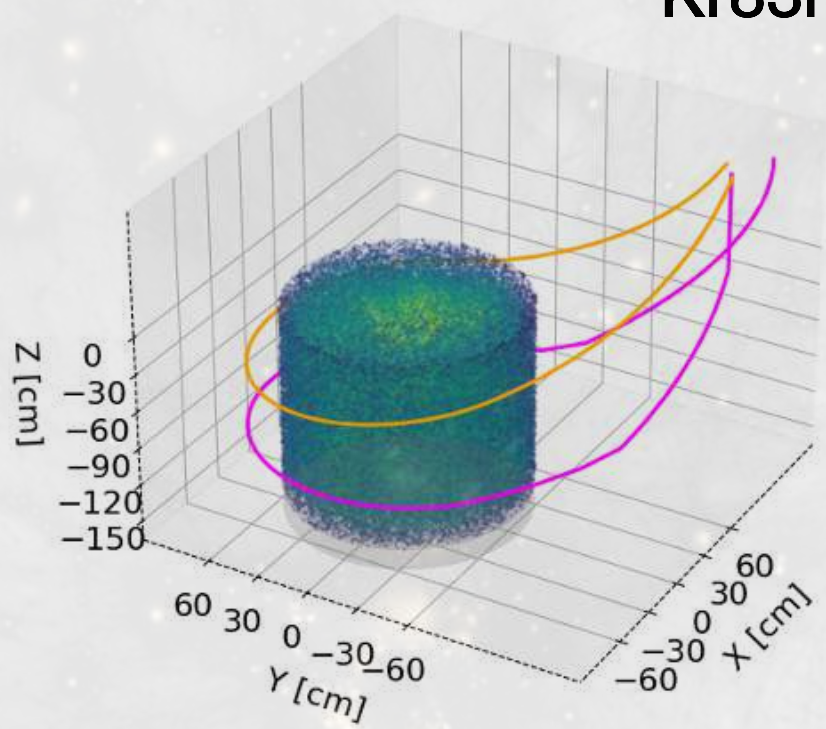
Exp	Max Drift [ms]	Electron lifetime [ms]	Cathode electron survival	Purification speed
XENON1T	0.73	0.65	30%	0.65ms in ~ 3 months
XENONnT	2.2	~10	>90%	5ms in ~5 days



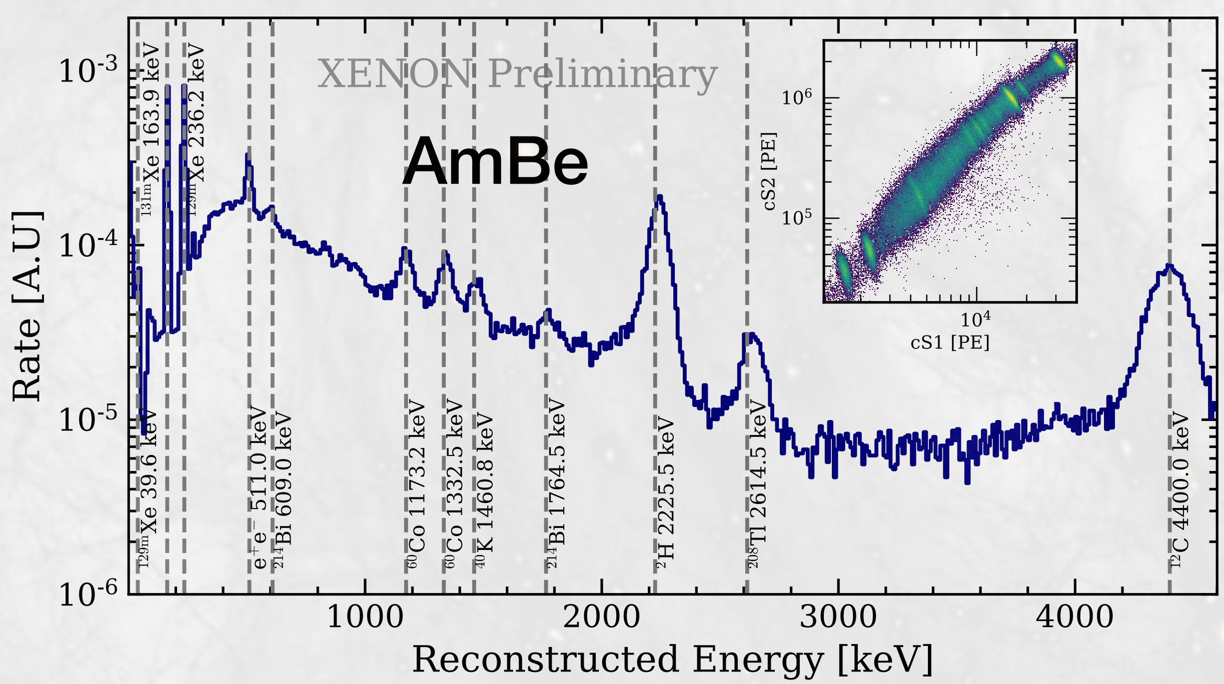
Calibrating XENONnT

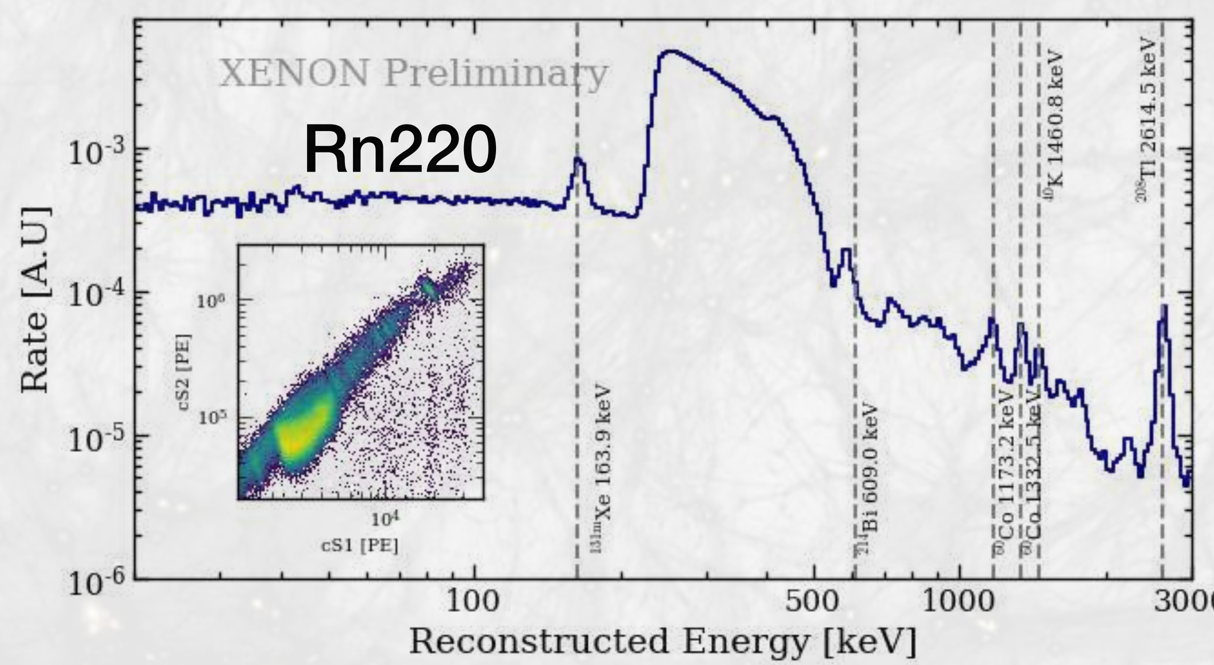
- XENONnT's 5.9-ton LXe sensitive volume is calibrated from keV to MeV

Kr83m

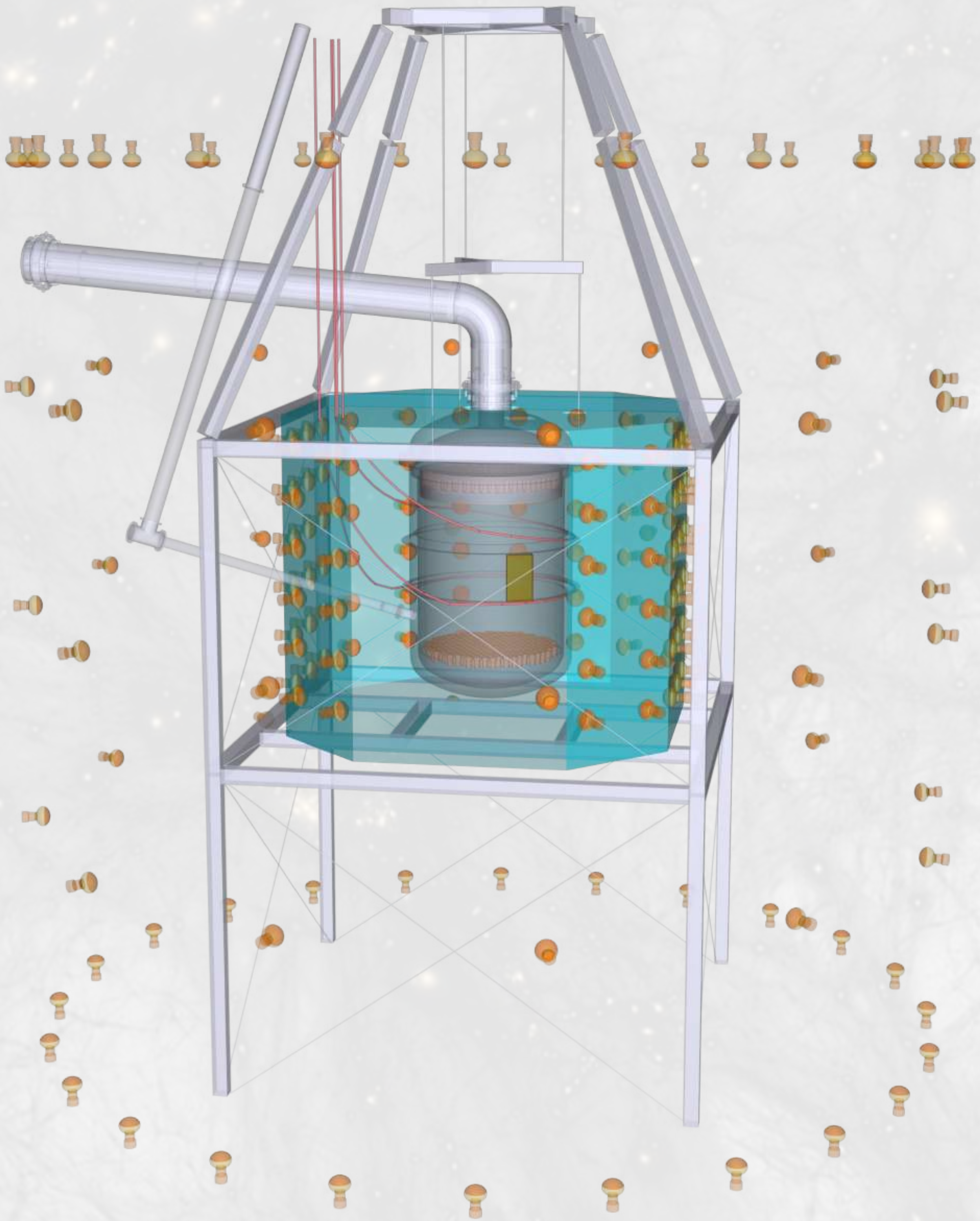


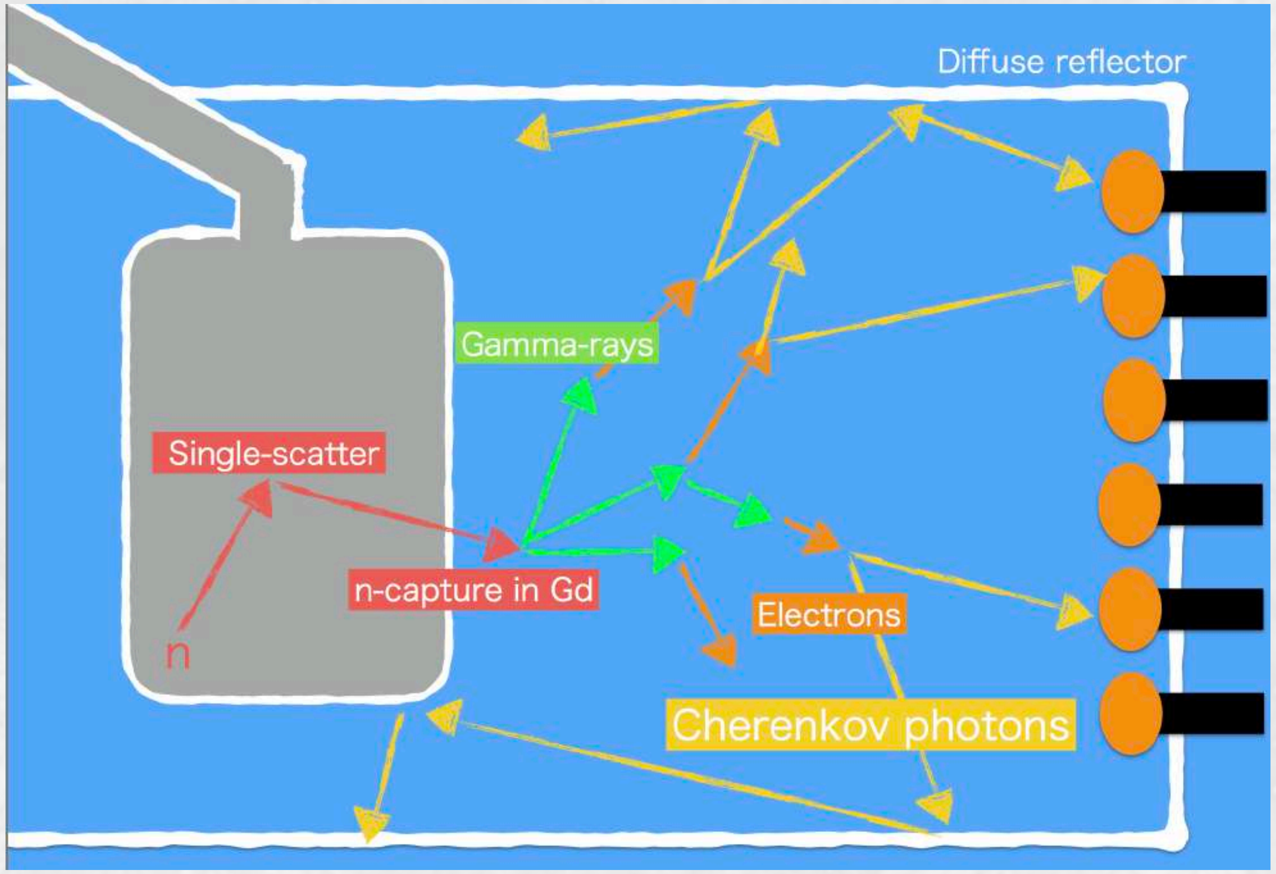
- XENONnT Calibration Campaign
  - Kr83m: uniformity, light/charge yield etc
  - Rn220: Low Energy ERs
  - AmBe: Low Energy NRs, high energy ERs
  - Other calibrations: PMTs etc





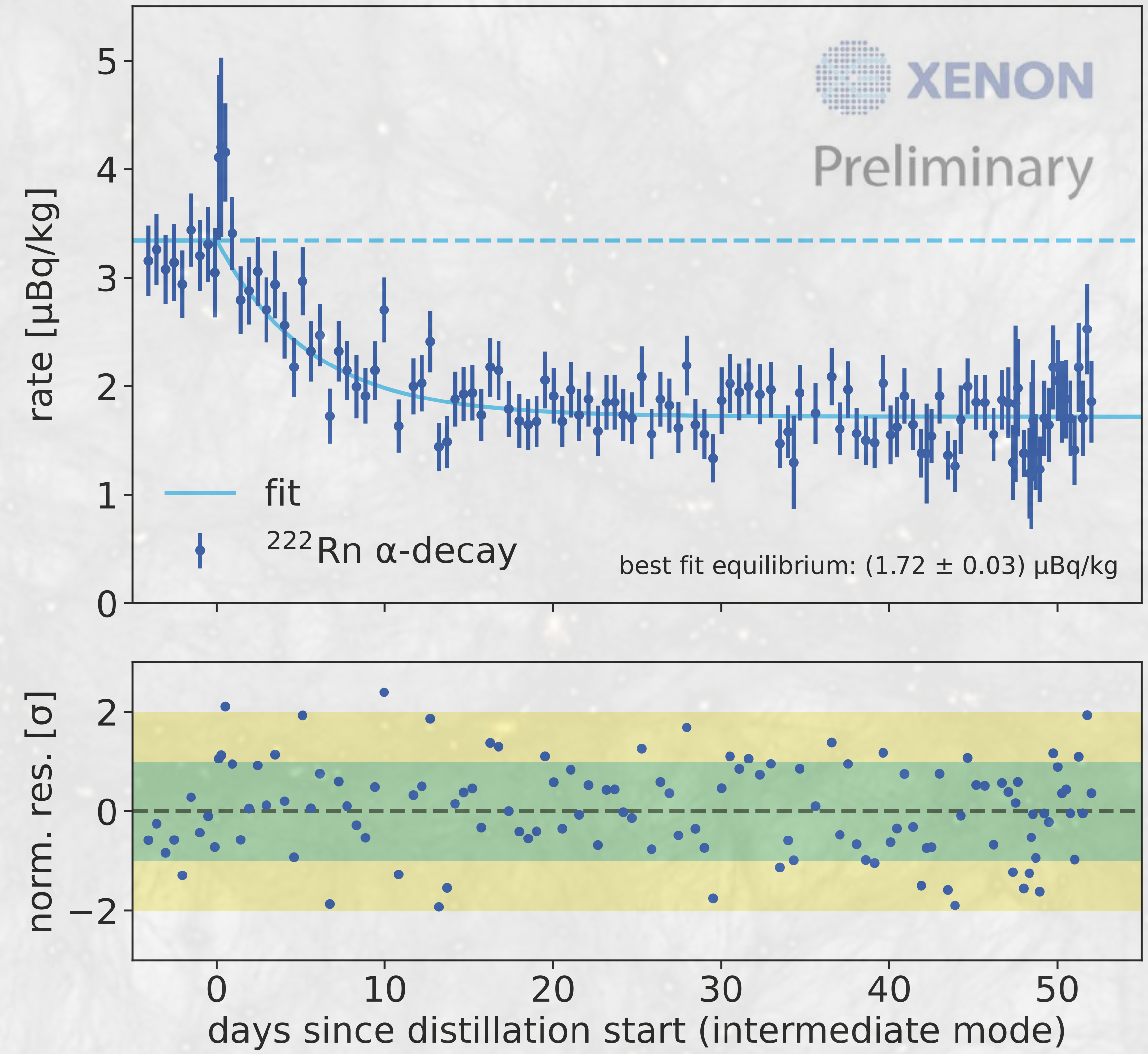
XENONnT Neutron Veto





- Gd-Water Cherenkov veto detection (designed efficiency >85%)
- Neutron background reduced to < 1 events / (20 tonne year)

XENONnT Radon Distillation Column



- Initial gas phase only distillation reduced the radon level to 1.7 μBq/kg
- Lowest radon level ever achieved in a LXeTPC

Summary

XENON1T: Still leading the search of many rare phenomena:

- WIMPs search
- Solar B8 “Neutrino Fog”
- Solar Axions
- ……

XENONnT: running at Gran Sasso

- lower background
- larger exposure
- higher sensitivity